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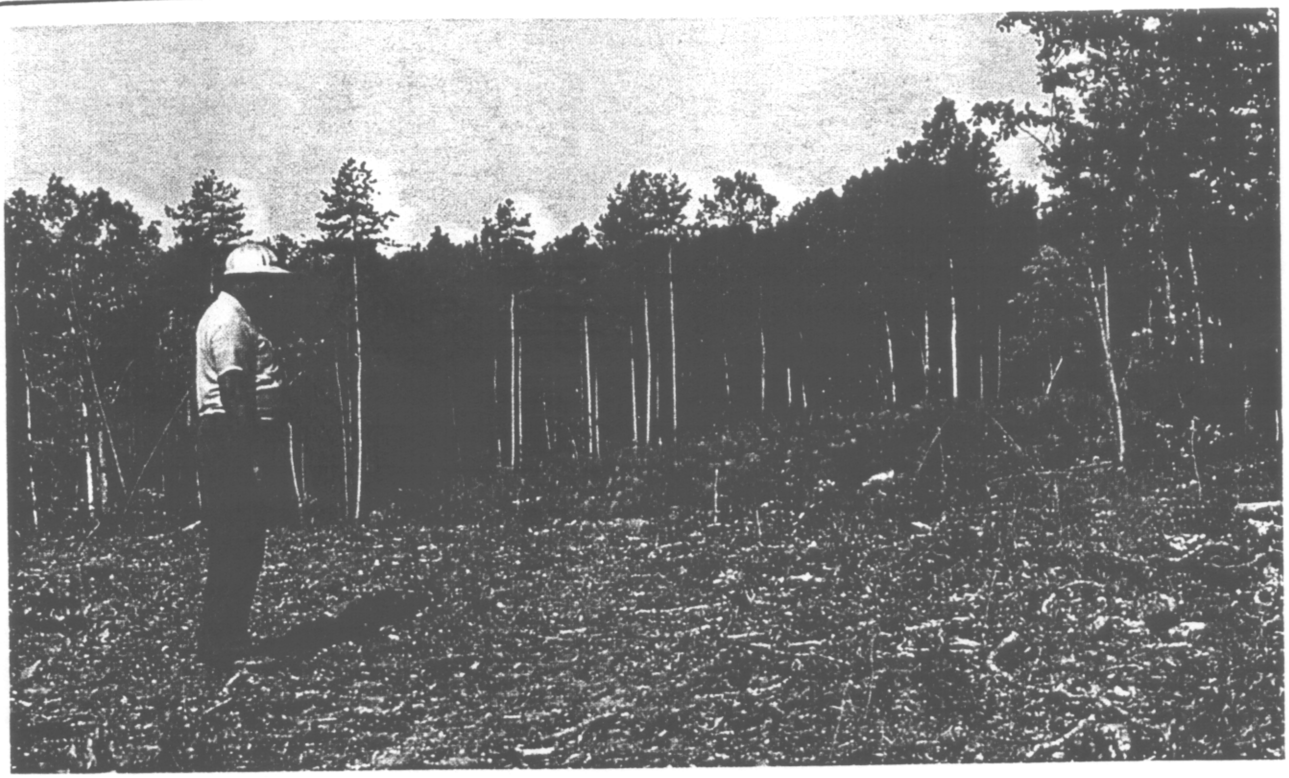

NUTRIENT REMOVAL UNDER WHOLE-TREE UTILIZATION FOR FUEL CHIPS

by
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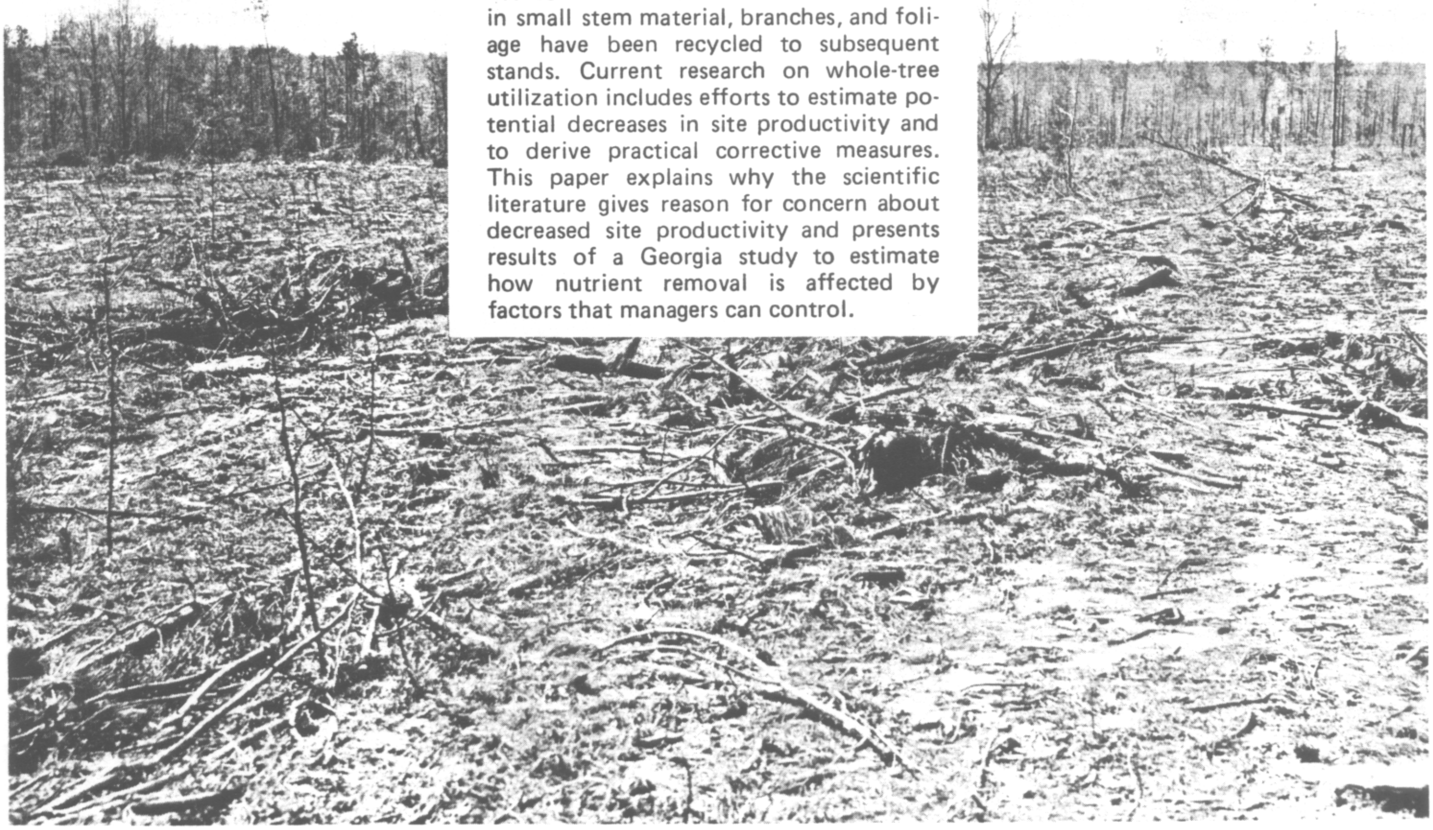
Today's advanced combustion systems can utilize woody biomass fuels produced from mixtures that include stems, branches, and even foliage from poor-quality trees. This development in conjunction with whole-tree chipping systems offers potential solutions both to many local energy needs and to the problem of how to get rid of commercially unproductive timber occupying what could be productive forest sites. Most forest management operations, however, affect nutrient cycling (Tamm 1979), and managers are concerned that intensive utilization of biomass could cause a decline in the economic productivity of the land. None of the branches and tops and only a portion of the stem material is removed from a site by conventional harvesting for nonfuel products. Therefore, most evidence related to sustained productivity has come from sites where the nutrients in small stem material, branches, and foliage have been recycled to subsequent stands. Current research on whole-tree utilization includes efforts to estimate potential decreases in site productivity and to derive practical corrective measures. This paper explains why the scientific literature gives reason for concern about decreased site productivity and presents results of a Georgia study to estimate how nutrient removal is affected by factors that managers can control.



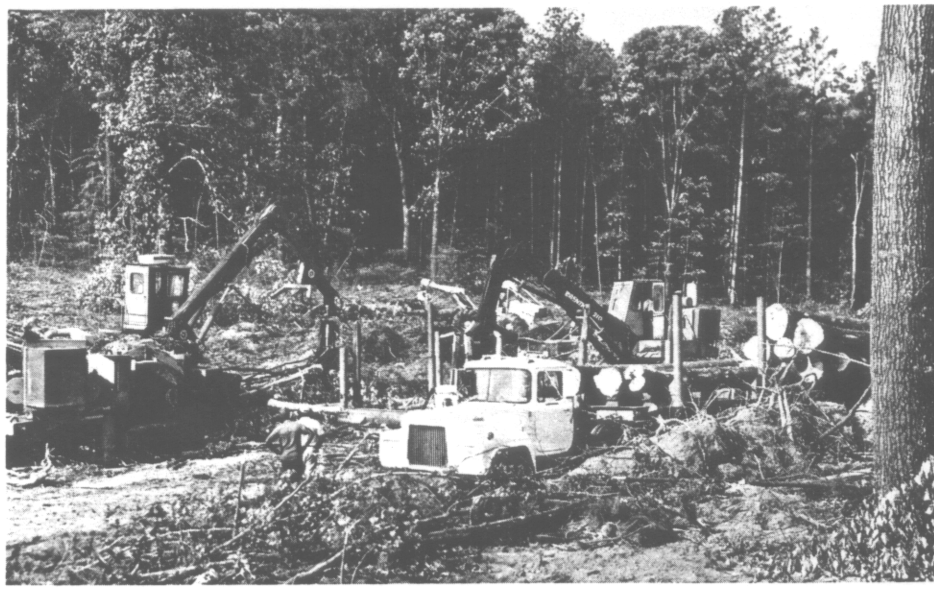
Nutrient Distribution in the Forest

Scientists often partition forest ecosystems into aboveground biomass, roots, forest floor, and soil. The quantities of nutrients contained in these various components are referred to as "nutrient pools." In the context of whole-tree utilization it is important to know how nutrients are distributed among various tree components, as well as to have estimates of the site nutrient pools. Our review has been assembled to provide general information about the average distribution of nutrients in the forest: the landowner should be aware, however, that there can be substantial departures from these general averages in individual cases.

Brady (1974) notes that nitrogen has probably been studied more than any other plant nutrient and that emphasis on this element is justified. Nitrogen is commonly the nutrient most limiting to productivity in forest ecosystems. The percentage distribution of the other major nutrients among tree and ecosystem components is usually similar to that of nitrogen, although the total quantities of each may differ. The only source of nitrogen to the stand is the atmosphere; no nitrogen becomes available from geologic weathering as do other nutrients. Because of its importance, much of our review focuses on nitrogen.

In forests of the Southeast, generally, one might expect 10-15 percent of the total biomass to be made up of roots, which contain 15-20 percent of the total tree nitrogen (Marion 1979). The logging systems that are currently operational over the region do not remove roots, so our concern is with the aboveground biomass components. The characteristics of these components differ between hardwoods and conifers. Nearly 11 percent of conifer biomass is in the branches and needles, which account for 40 percent of the aboveground nitrogen (Table 1). Hardwood branches and leaves account for nearly 26 percent of the aboveground biomass, but contain over 60 percent of the nitrogen. Hence the ratio of nutrient to biomass removal increases with more complete utilization and the increase is greater for hardwoods than for conifers.

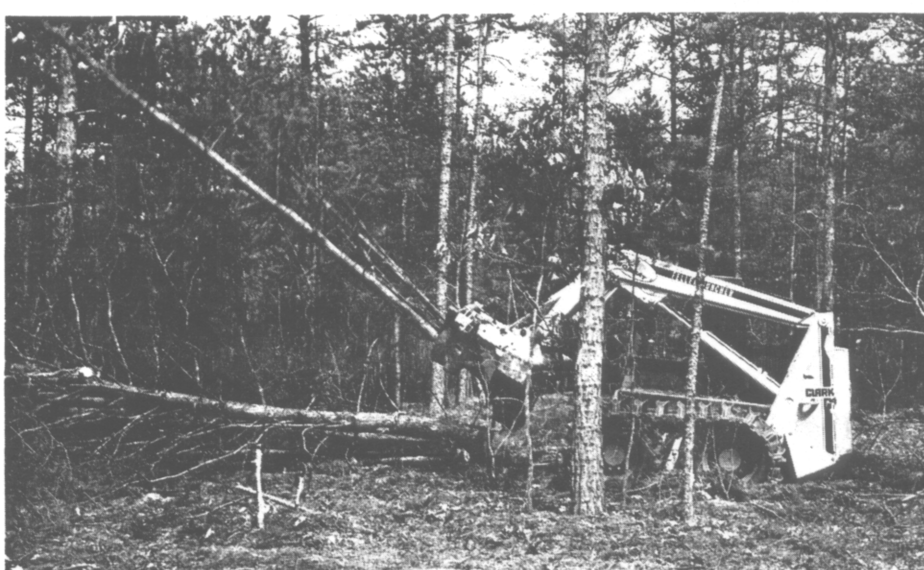
In a given region the absolute amount of nutrients in the aboveground biomass is also typically greater for hardwoods than for pines. The oak/hickory data in Table 2 are from Tennessee and the other two data sets (loblolly pine and oak/hickory/maple) are from North Carolina. These comparisons do not suggest that establishing and harvesting hardwoods will necessarily remove more nutrients than establishing and harvesting pines on the same site. Pines usually become established following some major soil disturbance and hardwoods follow pines in the natural succession of forest species. Therefore, sites naturally occupied by hardwoods have generally undergone a longer period of soil-building ecological succession than sites naturally occupied by pines.



Whole-tree chippers provide the capacity to use previously unmerchantable material.

Ecological differences between pine and hardwood situations are even more pronounced when the soil nutrient pool, itself, is considered (Table 3). On the loblolly pine site the soil nitrogen pool is almost seven times that of the biomass nitrogen pool, but on the mature oak/hickory site the ratio of soil to biomass nitrogen is greater than 14 to 1. These large pools of nitrogen exist primarily in unavailable organic form, and only gradually become available for tree growth through decomposition. As nitrogen does become available, however, it is readily taken up by plants. The very low levels of nutrients in water leached through forest soils indicate that forests in general exhibit rather tight nutrient cycles.

In the Southeast, leaching of nitrogen even from recently harvested forest stands is quite low. Increased soil moisture and temperature resulting from harvesting causes an increased rate of decomposition. However, the favorable climate in the Southeast permits rapid revegetation by vines, woody sprouts and seedlings, and herbaceous plants that effect immediate nutrient uptake. The green area in the center of the cover photo illustrates vegetative cover just 6 months after harvesting all woody biomass from one of our research plots: the foreground is a similar plot immediately after harvest.



All woody vegetation on a site can be removed with the relatively new feller-buncher.

The Study

The study is located in the Upper Piedmont of Georgia on the Dawson Forest, Dawson County, which is managed by the Georgia Forestry Commission. Our short-term objective is to estimate nutrient removals by season and intensity of whole-tree harvesting, as well as to estimate site nutrient pools. Longer term observations will allow us to determine if basic site productivity is altered by these removals.

The site is typical of many cutover, mixed hardwood pine areas throughout the Upper Piedmont. The primary hardwoods were chestnut oak *(Quercus prinus* L.), northern red oak *(Quercus rubra* L.), post oak *(Quercus stellata* Wangenh.), scarlet oak *(Quercus coccinea* Muenchh.), southern red oak *(Quercus falcata* Michx.), and hickory *(Carya* spp.). The pines were loblolly *(Pinus taeda* L.) and shortleaf *(Pinus echinata Mill.). The mean* basal area was approximately 100 square feet per acre and was made up of about 65 percent hard hardwood, 10 percent soft hardwood, and 25 percent pine. The soils (Fannin fine sandy loam and Tallapoosa fine sandy loam) had at one time been farmed, abandoned, and then allowed to revert to forest. Prior to the Commission's assumption of management responsibility, the timber stands had been highgraded for pine and the best quality hardwood, leaving either no merchantable timber or a merchantable volume too low for conventional logging.

Fuel chip harvesting activities were carried out in both winter and summer at two intensities of harvest. The most intensive harvest removed all woody biomass down to and including a 1-inch diameter at breast height. Four inches is a generally accepted lower limit for economically feasible fuelwood harvesting in the local area. No other limits were considered because the stands would not support economical logging for conventional products: from an economic standpoint, they would be harvested for fuel or not at all. Each combination of season and harvest intensity, as well as an undisturbed control, was replicated three times in a completely randomized design on 1-acre logging plots. Before harvesting, a 100-percent cruise was completed on ½-acre measurement plots embedded within each 1-acre treatment plot. Stand data and nutrient samples of forest floor and soil were collected. During harvest, skidding was excluded from the ½-acre plots and all material from them was chipped, weighed, and sampled for nutrient and moisture content.

Table 1.--Comparative biomass and nitrogen distribution among aboveground tree components in conifers and hardwoods

Tree component	Conifers[1] Biomass	Conifers[1] Nitrogen	Hardwoods[1] Biomass	Hardwoods[1] Nitrogen
	Percent			
Stems	89	60	74	39
Branches	9	14	25	51
Foliage	2	26	1	10

1/ Adapted from Marion 1979.

Table 2.--Examples of aboveground nutrient content for loblolly pine and mixed hardwoods

Species	Nutrient[1] N	K	Ca
	Pounds/acre		
Loblolly total	343	189	182
Loblolly stem	261	150	159
Oak/hickory	419	303	874
Oak/hickory/maple	888	357	741
Mixed oak	359	160	1053[2]

1/ Loblolly pine adapted from Wells and Jorgensen 1979; mixed hardwoods adapted from Morrison and Foster 1979, and Johnson et al. 1982.

2/ Stands located on soils derived from limestone.

Table 3.--Aboveground biomass, forest floor, and soil nitrogen pools for a young loblolly pine stand and mature hardwood stands

Species	Forest ecosystem component[1] Biomass	Floor	Soil
	Pounds/acre		
Young loblolly pine	229	331	1,564
Mature oak/hickory	426	198	6,067
Mature mixed oak	359	134	2,766

1/ Adapted from Wells and Jorgensen 1979, and Johnson et al. 1982.

Table 4.--Average initial stands for whole-tree harvest treatments, Dawson Forest, Georgia

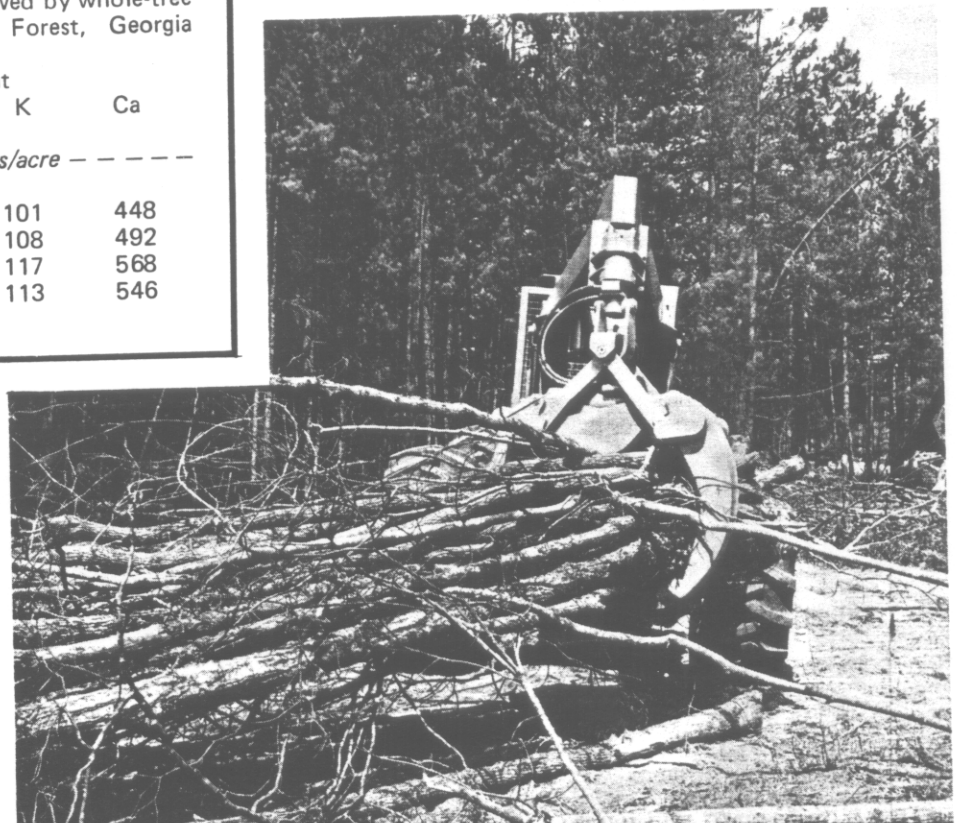
Treatment		Diameter class (inches)			
Season	Limit	<4	4-10	>10	Total
	Inches	— — — — — *Stems/acre* — — — — —			
Winter	4	848	165	20	1,033
	1	733	168	18	919
Summer	4	780	192	25	997
	1	755	191	22	968

Table 5.--Average nutrient pools of preharvest sites, Dawson Forest, Georgia

Component	Nutrient			
	N	P	K	Ca
	— — — — — —*Pounds/acre* — — — — — —			
Biomass	340	17.2	117	568
Forest floor	496	19.8	44	112
Soil	5,308	6.2	288	44
Total	6,144	43.2	449	724

Table 6.--Average mass of nutrients removed by whole-tree harvest treatments, Dawson Forest, Georgia

Treatment		Nutrient			
Season	Limit	N	P	K	Ca
	Inches	— — — — — *Pounds/acre* — — — — —			
Winter	4	238	13.6	101	448
	1	283	14.9	108	492
Summer	4	339	17.2	117	568
	1	340	16.8	113	546



This low grade timber, considered worthless just a few years ago, is being utilized in the wood energy market.

Results and Discussion

The average cruise data presented in Table 4 are fairly typical of cutover forest land in the Piedmont. The large number of stems in the lower diameter class account for only about one-fourth of the basal area per acre and about 20 percent of the biomass yield. The 1-inch limit harvest yielded approximately 75 green tons (45 dry tons) per acre and the 4-inch approximately 60 green tons (36 dry tons) per acre. The range in average moisture content of chipped material by treatment was only 67.2-68.5 percent and the range between the most extreme plots in the study was only about 61-72 percent (ovendry basis).

Nutrient pool estimates (Table 5) are consistent with published data presented earlier from the region. Forest floor and soil values are averages based on analyses of all preharvest samples. The biomass nutrient pool estimates are based on the highest average amount removed by any of the logging treatments (Table 6). The amount of nutrients removed as a proportion of the total site pool differs substantially by element. On average, our whole-tree harvests removed 5 percent of the nitrogen and 36, 24, and 71 percent of the phosphorous, potassium, and calcium, respectively. We should reemphasize here that the forest floor and soil values in Table 6 represent total quantities of nutrients only a portion of which is available at any given time for plant growth. Hence, longer term observations are necessary to estimate effects on sustained productivity. Onsite nutrients in organic form can become available to plants through mineralization brought about by decomposition and weathering and the total nutrient pool can be increased by mechanisms such as atmospheric deposition and nitrogen fixation.

Although we do not know the long-term effects of our most intensive harvest, we have found that there are steps a manager can take to limit removal of nutrients already contained in onsite biomass. From 20 to 40 percent more nitrogen was removed in the summer when the stands were in full foliage than in winter. Significant differences due to season also occurred for potassium and calcium. We can say with a high degree of confidence that nutrient removals can be moderated by harvesting during the dormant season, rather than the growing season.

Another finding is of substantial practical significance to many managers. No significant difference in nutrient removal occurred between the two harvest intensities in either season. One possible explanation is that the 1- to 4-inch stand component is comprised of suppressed stems with minimal nutrient demands. Removal of material in the 1- to 4-inch diameter range can be important from a site preparation standpoint. It appears from our results that if the decision has been made to harvest an area for the paying fuel, removal of this smaller material will have little added impact on site nutrient status.

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